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(19)

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(54) TOUCH SENSITIVE ELECTRICAL SWITCHES

(71) I, SECRETARY OF STATE FOR DEFENCE, London, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to electrical switches, particularly touch sensitive switches.

Most of the components employed nowadays in electronic equipment have been considerably miniaturised in recent years but many of the switches which are used are still quite bulky. Attempts have been made to simplify switches mechanically and touch sensitive switches, which avoid the use of moving parts, have been produced and have found common use in lifts (elevators) for a number of years. These usually operate in response to the change in capacitance of an electrical circuit provided by the human touch. These switches are normally employed as indicator switches, e.g. for indicating the floor to which a lift is travelling, and little reduction in overall compactness is afforded since the switch and its indicator, e.g. lamp, are both discrete bulky components and the overall switch circuit containing them is therefore bulky.

According to the present invention a touch sensitive electrical switch arrangement includes a first electrically insulating substrate having an inner surface bearing an inner electrode structure, a second electrically insulating substrate which is optically transparent having an inner surface bearing an optically transparent inner electrode structure and an outer surface bearing an optically transparent outer electrode structure, a layer of liquid crystal material contained between the substrate inner surfaces, a sensor for detecting electrical capacitance change when the outer electrode structure is touched by a human, the sensor having an input connection from at least one inner electrode structure on one of the substrates and an output connection to liquid crystal driver means having an output connection to at least one of the inner electrode structures for switching an optical state of the liquid crystal material when the outer electrode structure has been touched.

The substrates, electrode structures and liquid crystal material provide a single integrated touch switch-indicator construction. The sensor, and the liquid crystal driver means may conveniently be made from conventional integrated circuits, e.g. fabricated using large scale integration (LSI), and the driver output may be used directly to drive, i.e. switch the state of, the liquid crystal material. The arrangement may be battery operated and consequently fabricated in an overall single compact integrated package.

In one form of the invention the two inner electrode structures are multiplexed between the sensor and the driver means by electronic switches, so that the inner electrode structures are time shared between the alternate functions of sensing capacitance change and applying liquid crystal drive voltage (when necessary).

In an alternative form of the invention the second inner electrode structure comprises two pairs of physically separate electrodes, one pair being connected to the sensor, the other pair being connected to the driver means.

The first substrate and its inner electrode structure may be optically transparent and the liquid crystal material may be transparent in one of its optical states, i.e. when the outer electrode structure is or is not touched. This allows the operator to see through the construction to the region behind the first substrate where there may be located an additional indicator, e.g. a fixed sign or display saying "ON" or "OFF" or some similar caption.

In one particular form of the invention the arrangement may be a matrixed array of touch sensitive switches provided by a matrix of outer touch electrodes on the second substrate, a series of rows and columns of electrodes on the inner surfaces intersecting (with the liquid crystal material between) at places facing the touch electrodes. This form of the invention is sensitive to and indicative of the specific area touched in that the region of the liquid crystal material switched in state may be confined to that facing the specific outer touch electrode which is touched.

The liquid crystal material may for example be a cholesteric material which undergoes the well known "phase change" effect when switched. This material may be dyed to enhance its opacity in the state when the outer touch electrode is not touched.

Embodiments of the invention will now be described by way of example with reference to the drawings accompanying the provisional specification, in which:

Figure 1 is a cross-sectional view of a liquid crystal touch switch construction;

Figures 2 and 3 are cross-sectional views on the lines II—II and III—III respectively of substrate inner surfaces and electrodes in the construction shown in Figure 1;

Figure 4 is a circuit diagram of the switch construction shown in Figures 1, 2 and 3 together with an example of an associated sensor/control circuit;

Figure 5 is a circuit diagram of an alternative switch construction and sensor/control circuit;

Figure 6 is a waveform diagram illustrating operation of the construction and circuit shown in Figure 5;

Figure 7 is a circuit diagram of one example of part of the circuit shown in Figure 5; and

Figure 8 is an exploded perspective view of an electrode pattern on the substrate surfaces of a construction alternative to that shown in Figure 1.

In the construction shown in Figures 1, 2 and 3 two substrates 1, 3 made of glass or transparent plastics material are held apart by an annular plastics material spacer 5 which confines a layer LC of liquid crystal material between them. The outer surface of the substrate 3 has an outer optically tranparent touch electrode 9 made for example from a coating of a transparent conducting material, e.g. tin oxide, on its outer surface.

The inner surfaces of the substrates 1, 3 have electrode coatings as shown in Figures 2 and 3 respectively. The substrate 1 has a rectangular electrode 11 covering an interior area of the surface. The substrate 3 has a first pair of optically transparent rectangular electrodes 13, 15 together occupying an area facing that occupied by the electrode 11 and having connecting strips 17, 19 respectively. The substrate 3 also has a second pair of bridge-shaped optically transparent electrodes 21, 23 formed around the electrodes 13, 15 and the strips 17 and 19.

The electrodes 11, 13 and 15 constitute drive electrodes to drive, i.e. switch the state of, the liquid crystal layer LC. The electrodes 21 and 23 are sensor electrodes used in the sensing of capacitance changes when the touch electrode 9 is touched.

Operation will now be described with reference to Figure 4 which shows one example of a sensor/control circuit used in conjunction with the switch construction shown in Figure 1. A pulse generator 25 feeds a continuous series of voltage pulses in parallel to the electrode 21 and to one plate of a capacitor C1 whose other plate is connected through a resistor R1 to ground. An identical resistor R2 also connected at one end to ground has its other end connected to the electrode 23. The non-grounded ends of the resistors R1, R2 also form two inputs to an exclusive OR gate 31, preferably a CMOS gate having a very high input impedance e.g. 20 MΩ. The gate 31 has an output connection to a control logic unit 32, which may for example be a conventional interconnected logic circuit consisting of CMOS devices. The control logic unit 32 applies, when required, an output voltage between the electrodes 13, 15 via conductors 33, 35 respectively connected to the strips 17, 19 (Figure 3). This voltage drives the layer LC of liquid crystal material, i.e. switches it into its ON state.

Since the substrate 3 is a dielectric two capacitors C2 and C3 exist in this dielectric respectively between the electrode 21 and the electrode 9 and between the electrode 23 and the electrode 9.

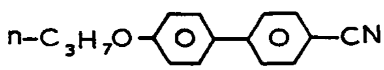
When the electrode 9 is untouched the capacitance of the capacitor C1 matches the overall capacitance of the capacitors C2 and C3, about 10 pF, and the voltages applied to the two parallel inputs to the gate 31 are balanced, i.e. equal. Consequently, the gate 31 applies zero output to the control logic 32 which maintains the liquid crystal layer LC in its 'OFF' state: for example for a dyed phase-change effect the layer LC is coloured in the 'OFF' state.

If the touch electrode 9 is now touched by a human a capacitance C4 of between about 150 and 225 pF, depending on the person's size, is introduced between the electrode 9 and ground. The voltage at electrode 23 is consequently reduced to approximately one tenth of that at the capacitor C1 because of this capacitance change. As a result of this voltage imbalance the gate 31 consequently applies an output, consisting of the series of voltage pulses fed from the pulse generator 25 via the capacitor C1, to trigger the control logic unit 32 which applies a conventional drive voltage to the liquid crystal layer LC causing the layer to change into its 'ON' state. For example for a dyed phase change effect the 'ON' state is clear. If an additional indicator or display (not shown) is located behind the substrate 1 (Figure 1) the indicator or display may now be observed.

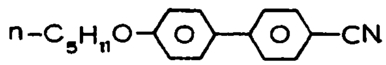
Half of the liquid crystal drive voltage from the control logic unit 32 appears between the electrodes 13 and 11 whilst the other half appears between the electrodes 11 and 15. In other words the threshold of the liquid crystal effect is doubled by applyig the voltage in two stages. However, applying the voltage in this way minimises unwanted capacitance inter-

actions between the liquid crystal layer LC and the sensor electrodes arising as a result of the electrodes 13, 15, 21 and 23 all being on the same surface of the substrate 3.

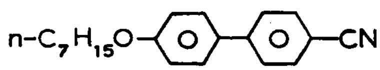
The liquid crystal material employed in the liquid crystal layer LC may for example be a cholesteric-to-nematic phase-change material comprising the following mixture:



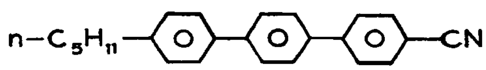
14% by weight



36% by weight



36% by weight



9% by weight

cholesteryl nonanoate 5% by weight

The liquid crystal material may be dyed by one of the dyes described in UK Patent Applications 25843/75 and 25859/75.

Figure 5 is a schematic circuit diagram showing an alternative touch switch construction and sensing/control circuit. In this case the substrates 1, 3 and liquid crystal layer LC are as shown in Figures 1 to 3 but the substrate 3 has a single unpatterned electrode 37 facing the electrode 11. The electrode 37 is connected to one terminal on one sde of an electronic switch 41 and the electrode 11 is connected to a similar terminal of an electronic switch 43. Each of the switches 41, 43 has two terminals on its other side, one connected to a liquid crystal drive unit 45 and the other connected to a sensing circuit 47. The switches 41, 43 have a 'zero' state and a 'one' state and switching between them is carried out by a common interrogation signal. In the zero state the electrodes 11, 37 are connected by the switches 41, 43 to the liquid crystal drive unit 45. In the one state the electrodes 11, 37 are effectively short circuited together and form a single input to the sensing circuit 47. Preferably, the switches 41, 43 are conventional CMOS switches.

Figure 6 illustrates one mode of operation of the arrangement shown in Figure 5. The interrogation signal consists of a sequence of interrogation pulses. The zero state in which the switches 41, 43 are connected to the drive unit 45 occurs between the interrogation pulses, and the one state in which the switches 41, 43 are connected together and to the sensing circuit 47 occurs during the pulses. Thus sensing of a touch only occurs during the interrogation pulses. When no touch is present the capacitance from the electrode 9 to ground is zero. However, when the electrode 9 is touched this capacitance is large as explained above. The increase in capacitance is sensed during the next interrogation pulse causing the sensing circuit 47 to give an output which triggers the drive unit 45. As soon as the interrogation pulse ends and the switches 41, 43 revert to their zero state the drive unit 45 applies a drive voltage which is shown in Figure 6 as a pulsed signal.

Although the output of the sensing circuit 47 which triggers the drive unit 45 is shown in Figure 5 as a positive signal it may alternatively be a negative signal as in the following example.

Figure 7 shows one example of the sensing circuit 47. The electrodes 11 and 37 are assumed to be temporarily short-circuited together, i.e. during the ONE state of the switches 41, 43. A capacitor C5 exists between the electrodes 37 and 9. The electrode 37 is connected at a common point X to one plate of a capacitor C6 and one end of a resistor R3 having a very high resistance. The other end of the resistor R3 is grounded.

Two CMOS inverters 49 and 51 having a combined impedance less than that of the resistor R3 are connected in series to the common point X.

A pulse train which may or may not be the interrogation signal (Figure 6) is applied to the plate of the capacitor C6 remote from the point X. This pulse train is effectively transmitted through the capacitor C6 and appears at the point X. If the electrode 9 is untouched the pulse train is sensed by the inverters 49 and 51 because the impedance of the resistor R3 is sufficient to make the voltage at X higher than the threshold of the CMOS inverters 49, 51. The capacitor C5 is effectively in series with zero capacitance to ground and

the overall impedance of the arm containing the capacitor C5 is essentially infinite. However, when the electrode 9 is touched a large capacitance C4 to ground appears in series with the capacitor C5. The impedance presented to the pulse train by the capacitances C4 and C5 is now much less than that presented by the resistor R3 and the voltage at X is reduced due to this impedance reduction. The output of the inverters 49 and 51 is now zero. The liquid crystal drive unit 45 (Figure 5) is logic constructed to give an output only for zero input.

The inverters 49, 51 are provided to detect the change in voltage at X and to interface with the logic of the drive unit 45.

In an alternative embodiment of the invention the substrates 1, 3 and the liquid crystal layer LC are as shown in Figure 1 but the electrodes on the surfaces of the substrates 1, 3 are as shown in Figure 8, (the substrates 1, 3 and the liquid crystal layer LC being omitted for clarity).

The substrate 3 has a matrix of four electrodes 20, 22, 24 and 26 on its outer surface and a matrix of four electrodes 28, 30, 34 and 36 on its inner surface respectively facing the electrodes 20, 22, 24 and 26. The substrate 1 has on its inner surface only a matrix of four electrodes 38, 40, 42, 44 respectively facing the electrodes 28, 30, 34 and 36. The electrodes 40 and 42 are connected together by a conducting strip 46, and the electrodes 38 and 44 are connected together by a conducting strip 48. The electrodes 28 and 30 are connected together by a conducting strip 50, and the electrodes 34 and 37 are connected together by a conducting strip 52. The strips 46 and 48 are perpendicular to the strips 50 and 52.

In this case the arrangement operates on the same principles as described with reference to Figure 5 but is additionally able to sense and indicate which of the touch electrodes has been touched individually. Each of the strips 50, 52, 46 and 48 is connected through a switch (not shown) similar to the switches 41, 43 (Figure 5) to a sensing circuit (not shown). Touching of one of the electrodes 20, 22, 24, 26 is sensed by applying interrogation pulses to the strips 46, 48, 50, 52 and detecting coincidence between outputs from the sensing circuits connected to those strips.

Each switch and sensing circuit may be common to one of the two pairs of strips, i.e. the strips 46, 48 or the strips 50 and 52, and the interrogation pulses may be applied in a known multiplexed fashion.

The liquid crystal drive pulse is applied between interrogation pulses from a drive unit (not shown) in response to coincidences between outputs of the sensing circuits. The drive pulse is selectively applied only to the appropriate two strips which intersect facing the touched electrode.

Possible uses of the touch switch arrangements described above are as follows: (a) in association with bistable logic where the liquid crystal layer LC gives an indication of the state of the logic; (b) as alarm indicators, e.g. where an alarm is given by the liquid crystal layer LC and touching the touch electrode disables the alarm; (c) for changing the data displayed on a digital readout, e.g. from a time readout to a date readout on a watch.

The touch switch arrangements described above may be wholly optically transparent for one of the optical states of the liquid crystal material. E.g. the substrate 1 and the electrode 11 of figures 1, 2 and 3 may also be optically transparent. In this form the switch may be used as an overlay for an indicator. The indicator may be for example another liquid crystal display device, or a display including one or more light emitting diodes.

WHAT I CLAIM IS:—

1. A touch sensitive electrical switch arrangement including a first electrically insulating substrate having an inner surface bearing an inner electrode structure, a second electrically insulating substrate which is optically transparent having an inner surface bearing an optically transparent inner electrode structure and an outer surface bearing an optically transparent outer electrode structure, a layer of liquid crystal material contained between the substrate inner surfaces, a sensor for detecting electrical capacitance change when the outer electrode structure is touched by a human, the sensor having an input connection from at least one inner electrode structure on one of the substrates and an output connection to liquid crystal driver means having an output connection to at least one of the inner electrode structures for switching an optical state of the liquid crystal material when the outer electrode structure has been touched.

2. An arrangement as claimed in claim 1 and wherein the first substrate and its inner electrode structure are optically transparent and the liquid crystal material is transparent in one of its optical states controlled by the driver means.

3. An arrangement as claimed in claim 2 and including an indicator behind the first substrate.

4. An arrangement as claimed in claim 1, 2 or 3, wherein one of the inner electrode structures is connected to a first electronic switch so that it may be connected alternately to the input of the sensor and to one output of the crystal driver means, the other inner electrode structure being connected to a second electronic switch so that it may be connected alternately to the input of the sensor and to another output of the crystal driver means, the first and second electronic switches being connected such that the arrangement may be alternated from a sensing mode to a driving mode.

5. An arrangement as claimed in claim 1, 2 or 3, wherein the second inner electrode structure comprises 4 electrodes, two of these electrodes being symmetrically disposed with respect to each other and in facing register with the first inner electrode structure, the other two electrodes being symmetrically disposed to each other and to the two electrodes first mentioned, being disposed around these two the two innermost electrodes being connected across the driver means, the two outermost electrodes being connected across the sensor.

6. An arrangement as claimed in claim 5 wherein the sensor includes an alternating current bridge, the sensor having two inputs connected one to each of the two outermost electrodes, the two outermost electrodes being cooperative with the outer electrode structure to provide a capacitance across the two sensor inputs and providing thereby one arm of the bridge, the sensor means also including a pulse generator connected for energising the bridge, and detector logic means connected across the bridge to detect the condition of the bridge and to provide at the sensor output a control signal dependent on the condition of the bridge, the condition of the bridge in use being of one of two states according to whether the outer electrode is touched by a human.

7. An arrangement as claimed in claim 1, 2 or 3 wherein the inner electrode structures each comprise a plurality of electrodes, these electrodes being arranged in row and column matrix format respectively; the outer electrode structure also comprising a plurality of electrodes, one electrode corresponding to each matrix intersection; the connections between the inner electrode structures, the sensor and the driver means being multiplexed so that a localised region of the liquid crystal layer at a matrix intersection is switched when, in use, the corresponding electrode of the outer electrode structure is touched by human.

8. Any one of the touch sensitive switch arrangements constructed adapted and arranged to operate as hereinbefore described with reference to and as illustrated in figure 4, or in figures 1, 2, 3 and 4, or figure 5, or figures 5, 6 and 7 of the drawings accompanying the Provisional Specification.

9. A touch sensitive switch arrangement as claimed in claim 1 including inner and outer electrode structures constructed adapted and arranged to operate as hereinbefore described with reference to and as illustrated in figure 8 of the drawings accompanying the Provisional Specification.

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Agent for the Applicant.

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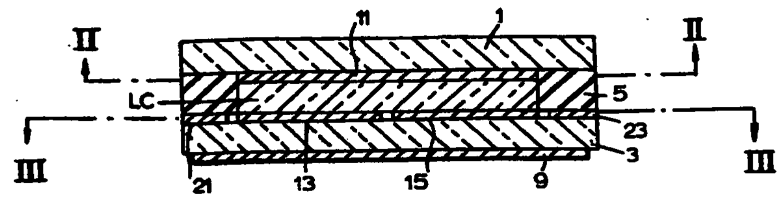

FIG. 1.

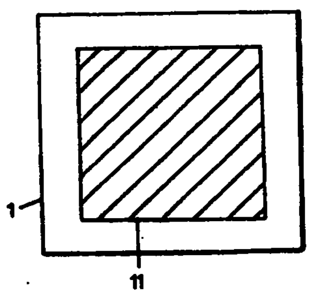

FIG. 2.

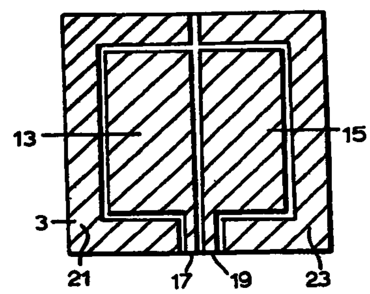

FIG. 3.

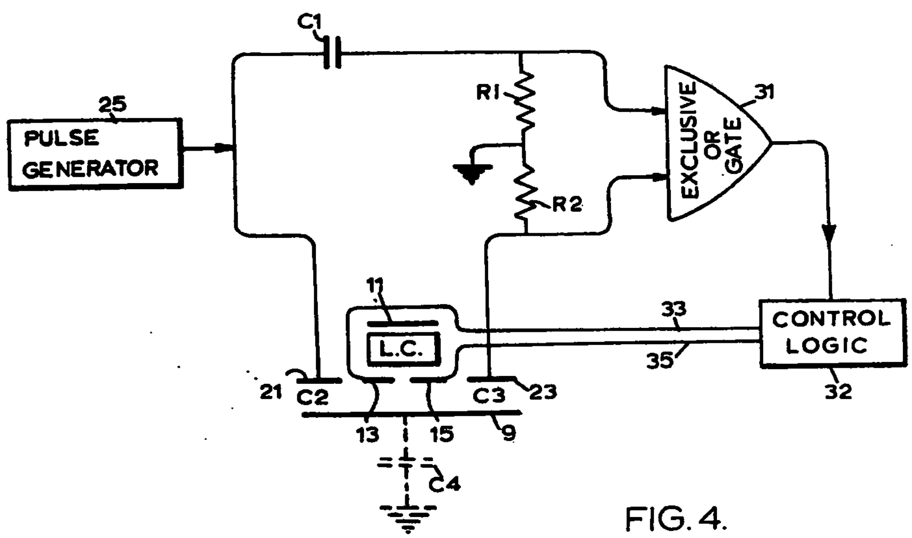

FIG. 4.

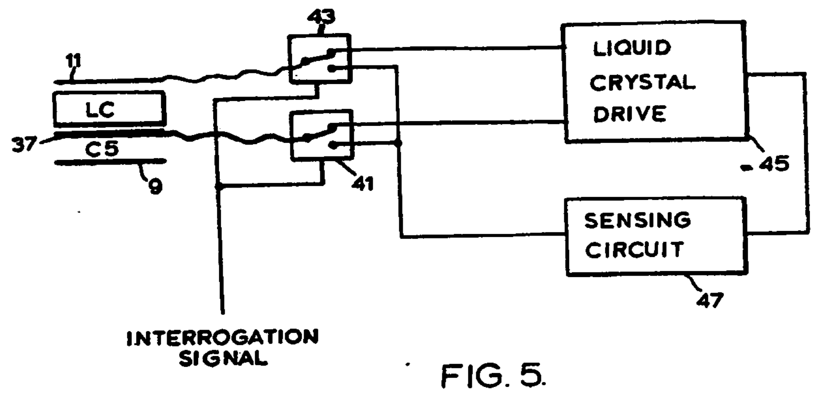

FIG. 5.

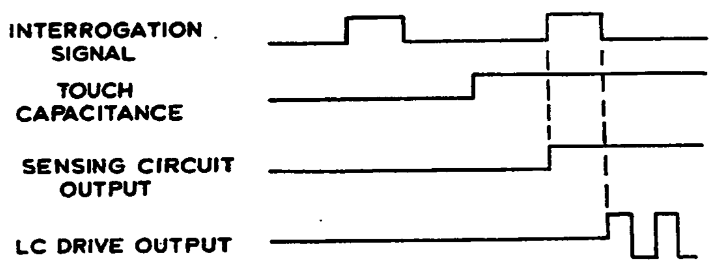

FIG. 6.

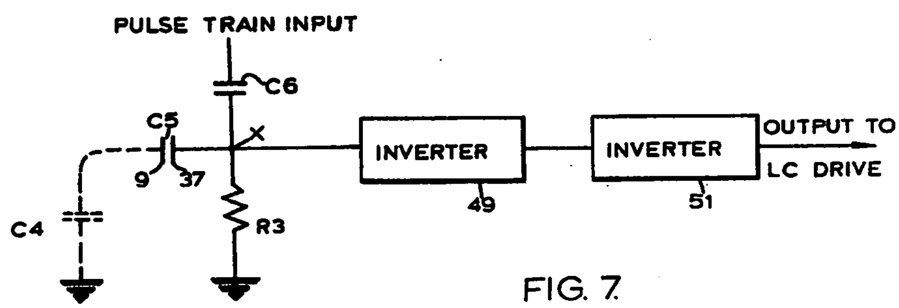

FIG. 7.

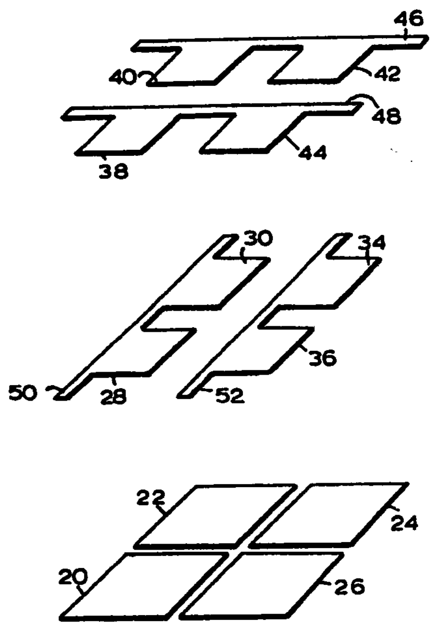

FIG. 8.